TITLE

New methods to measure accommodation facility

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KEYWORDS

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DISCLOSURE

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ABSTRACT

Purpose

To study the accommodative dynamics when the accommodative demand (AD) is changed in an unpredictable manner during an accommodative facility test.

Methods

Seventeen young healthy subjects (mean age ± standard deviation (SD) of 23 ± 2) were measured monocularly 2 consecutive times with 5 different tests. The first two were the conventional monocular accommodative facility tests for far and near distance performed with a manual flipper held by a clinician. The remaining 3 were automated and conducted using the electro-optical system with and open-field autorefractor. Two out of the 3 automated tests replicated the conventional accommodative facility tests for far and near distances. The last automated test was a hybrid approach where both far and near accommodative facility tests were automated and integrated into only one test that randomized among the 4 accommodative demands.

Results

The within-subject standard deviations for far and near distance obtained with the manual flipper accommodative facility test were: ±1 and ±1 cpm. Analogously for the automated test: ±3 and ±4 cpm. The 95% limits of agreement between the manual and the automated test for far and near distance were: (-18, 12) and (-15, 3). In regards to accommodation dynamics of the hybrid test: the response time and accommodative response were significantly ($p<0.05$) larger for accommodation than disaccommodation for high accommodative demands only. The response times during the transitions 0.17/2.17 D and 0.50/4.50 D were not significantly different between the hybrid and the conventional automated tests.

Conclusions

The automated accommodative facility test does not agree well with the manual flipper test for both far and near distances. It is likely that the operator delay when flipping the lens account for the differences. The hybrid test is able to provide a more comprehensive examination of the accommodative capability to change focus over time than the conventional accommodative facility test. Unexpectedly, the unpredictability of the stimulus did not to affect accommodation dynamics.

Keywords: Accommodative facility, accommodative dynamics, unpredicted stimuli, automated, agreement, repeatability.

INTRODUCTION

The ability of the eye to accurately and repeatedly change the accommodative state between two focal planes during a period of time is measured with the accommodative facility test.[1] This test is usually performed either at far distance (i.e., the fixation target is at 6 m distance) or at near distance (i.e., the fixation target is at 0.4 m distance) and the accommodative demand for each focal plane is lens-induced with an accommodation flipper: at near distance it is used a pair of ophthalmic lenses of +2 D and -2 D, which stimulates, respectively, +4.50 D and +0.50 D, and at far distance, it is only used a lens of -2 D, which is used to stimulate an accommodative demand of +2.17 D and +0.17 D (the latter one would correspond to a lens of zero power). This test is performed in children[2] and in young adults.[1] For children between 6 and 12 years old, 6 cycles per minute (cpm) or above is the expected finding when the test is performed monocularly in healthy subjects.[2] Analogously, between 13 and 30 years old, the expected finding is 11 cpm or above.[1] Accommodative facility is amplitude of accommodation dependent, prepresbyopic subjects from 30 to 42 years have difficulties following the previous normative values,[3] for that reason it was suggested by Yothers *et al*.[4] to use an amplitude scaled facility test where the accommodative demand was adjusted according to the amplitude of accommodation of each subject.

The accommodative facility test is used as a measure of visual fatigue,[5] which can be related to accommodative and/or binocular vision dysfunctions.[6] However, this test measures under repeated and predictable conditions, which is not a common situation occurring in natural conditions, where we are used to change focus in nearly infinite focal planes in a random or pseudo-random fashion during all day.

To our knowledge, no one have explored an accommodative facility test with more than two accommodative demands for a certain test distance, i.e., rather than repeat the same transition between two accommodative demands over time, new emerging technologies such as computer-controlled focus-tunable lens (electro-optical systems)[7] allow to include more accommodative states and randomize among them. These features can be useful: 1) to automatize the test; 2) to study how the accommodative facility test may be affected by any potential anticipation effect (due to stimulus' predictability);[8–11] and 3), to obtain a more comprehensive examination as the patient would have to clear more accommodative demands spread along the amplitude of accommodation. In addition, a focus-tunable lens can be used to further understand the dynamics of accommodation when optically stimulated. This latter point is especially relevant since it has been shown that the steady-state accommodative response stimulated with lens-based systems is affected by many factors such as the refractive error or the field of view when compared to free space stimulation.[12–14] Finally, a better understanding of the dynamics of accommodation under optical stimulation would also provide some insights into the visual discomfort that some subjects may experience in virtual reality systems.[15]

Having in mind all this, the purpose of this study is dual, first to compare the conventional manual flipper accommodative facility test with an automated test performed in a computer-controlled electro-optical system, and secondly, to study accommodation dynamics of a new accommodative facility test that flips among 4 accommodative demands in an unpredictable manner.

METHODS

Subjects

The study followed the tenets of the Declaration of Helsinki and all subjects gave informed written consent. Criteria for inclusion were: (1) best-corrected visual acuity of 0 logMAR (20/20 Snellen equivalent) or better in each eye, (2) amplitude of accommodation above the average given by Hofstetter's formula for accommodation20 (Amplitude = 15 – 0.25*Age), (3) between 18 and 25 years of age, to ensure that the amplitude is not a confounding factor in the accommodative facility test, (4) spherical equivalent error measured with subjective refraction between -6.50 and +0.50 D, (5) no strabismus, amblyopia, binocular or accommodative anomalies, and (6) no history of any ocular disease, surgery and/or pharmacological treatment that may have affected vision at the time of the study. All subjects have their full distance correction during testing with a soft contact lens, no subject had astigmatism greater than -0.50 DC.

Instrumentation and methods

There were 5 different conditions in this study summarized in table 1. The first two conditions were the conventional monocular accommodative facility tests for far and near distance. In these two cases the clinician hold an accommodation flipper in front of the patient's eye during 60 seconds. Every time the patient reported clarity of the target the clinician changed the accommodative demand. The remaining 3 conditions were conducted using the electro-optical system with an open-field autorefractor shown in figure 1 and explained in detail below. In these three cases, once the patient reported clarity by pressing a key on a keyboard the accommodative demand was automatically changed to the next accommodative demand. Conditions 3 and 4 replicated the conventional far and near distance accommodative facility tests of condition 1 and 2, thus the accommodative demand changed between 0.17 and 2.17 (far distance) or 0.50 and 4.50 D (near distance test). Finally, the condition 5 integrated the far and near accommodative facility tests into one test (hybrid test), thus, it comprised 4 possible accommodative demands that were pseudo-randomly chosen. The pseudo-random sequence forced 8 times each possible transition between two demands (e.g., 8 times the transition 0.17 to 2.17 D, 8 times the transition 4.50 to 2.17 D, etc.). There were 6 possible transitions for accommodation and 6 possible transitions for disaccommodation, therefore the test finished once the subject cleared 96 transitions (8x6x2=96). This allowed us to ensure the same accommodative demand changes (or '*overall effort*') in all subjects. In order to compare the dynamics measured with the autorefractor among conditions 3, 4 and 5, conditions 3 and 4 finished as well once the subject cleared 96 transitions (48x1x2), in these two conditions there was only one possible transition: either 0.17/2.17 D or 0.50/4.50 D.

A binocular open field autorefractor, PowerRef II (Plusoptix Inc., USA), was used to measure accommodation responses. This autorefractor is based on the principle of dynamic infrared retinoscopy and it measures spherical equivalent, pupil size and gaze position at a sampling frequency of 25 Hz.[16,17] In order to align the PowerRef and the subject's eye while allowing the target viewing, a 50 mm squared IR hot mirror was placed 40 mm from the subject's pupil plane. Subjects look at the accommodative stimulus through an optical system comprised by three lenses. A schematic representation of the setup and the stimulus can be seen in figure 1A. The first lens (L1, diameter of 50 mm, focal length of 100 mm) was placed 200 mm from the subject's pupil (twice f_{L1}). In this way, a pupil conjugate plane was created 200 mm away from the lens, without magnification. The active module that performed the accommodation stimulation was placed in that plane and was composed by an electro-optical lens (EOL, EL-16-40-TC, Optotune Switzerland AG, Switzerland) and a second lens (ophthalmic type) attached to it (L2, diameter of 25 mm, power of +3 D). The EOL had a spherical power range from -10 to +10 D, with a reproducibility of ± 0.05 D and a power settling time of 25 ms (according to manufacturer's specifications). Finally, the target was placed 6 meters away from the EOL. The proposed arrangement assured both the linearity and the 1:1 relationship between the power applied by the EOL and the accommodation stimulated to the subject, as well a constant size of the stimulus when changing in the accommodative demand. The role of lens L2 was to shift 3 D the working power range of the EOL in order to avoid its operation limits (far vision corresponds to an EOL power of +7 D, instead of +10 D), thus guaranteeing its best performance. The overall system could achieve an accommodative range up to 10 D, with a constant field of view of 14.25°. The response time for a step change of accommodative demand was around 40 ms (response time of the electronics + settling time of the EOL).

The EOL power was controlled by a current driver, which was connected to a PC and controlled by means of a software application specifically developed for this study. The different tests (conditions 3, 4 and 5) were automatically run by this software, performing the required accommodative demand changes, and synchronizing those changes with the PowerRef. In order to avoid possible thermal drifts on the EOL response, it was warmed up to 28 °C before beginning the measurement sessions, and kept in that temperature throughout the procedures. Moreover, the EOL response at that temperature was calibrated before its integration on the system by means of a digital lensmeter CL-300 (Topcon, Japan), including the calibration curve in the software application.

The accommodative stimulus in all 5 conditions was a black Maltese cross on a white uniform background (figure 1B). Even though this stimulus does not have peripheral depth cues, which could have improved the accommodative response,[13,18] it was chosen because it was found to elicit accurate enough accommodative responses,[12,19] it is easily reproducible and it allowed direct comparisons with previous accommodation dynamic studies.[20–22]

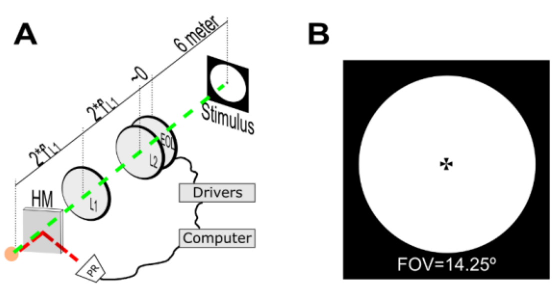

Figure 1. A: schematic view of the setup. B: accommodative stimulus used in the experiment. HM: Hot mirror. EOL: Electro-optical lens. PR: PowerRef II. f’: focal length.

Table 1. Summary of the experimental conditions.

Condition	Method	Distance	Accommodative Transitions (D)	Response variables
1	Manual Flippers	Far	0.17 / 2.17	Cycles/minute
2	Manual Flippers	Near	0.50 / 4.50	Cycles/minute
3	Automated (EOL system)	Far	0.17 / 2.17	Cycles/minute Latency Accommodative response Response time
4	Automated (EOL system)	Near	0.50 / 4.50	Cycles/minute Latency Accommodative response Response time
5	Automated (EOL system)	Far & Near (hybrid approach)	0.17 / 0.50 / 2.17 / 4.50	Latency Accommodative response Response time

Examination protocol

A monocular subjective refraction with endpoint criteria of maximum plus power that provides best visual acuity was performed to determine best optical correction. Monocular amplitude of accommodation was evaluated by averaging the values of two push-up and two push-down trials, to compensate for the bias of push-up to overestimate and push down to underestimate accommodation amplitude.[26]

Then, all five conditions previously described were measured in 2 sessions (test-retest) that took approximately 30 minutes each, including breaks. Subjects were allowed to take breaks as needed, although there was no systematic method to provide rests during the measurements. Randomization of configurations was rigorously applied to minimize potential learning or fatigue biases. The time between the 2 sessions was 15 minutes. In all conditions the fixation target was a black Maltese cross on a white surrounding and the same eye was measured (the contralateral eye was occluded with an eye patch).

Data analysis

Data was processed with Matlab R2015b (MathWorks, Inc., USA). Repeatability of far and near accommodative facility tests in both the manual (condition 1 and 2) and the automated tests (condition 3 and 4) were analyzed with the within-subject standard deviation and paired t-tests. Agreement between the manual flipper and the automated test at both target distances were analyzed with the 95% limits of agreement and paired t-tests. In both analysis (repeatability and agreement) the response variable was the number of cycles per minute.

The differences between the hybrid accommodative facility test (condition 5) and the conventional tests (condition 3 and 4) performed in the EOL system were analyzed with a repeated measures ANOVA with 3 within-subjects factors (with 2 levels each) conducted for the *latency, response time and accommodative response*. The within-subjects factors were: test {*conventional or hybrid*}, distance {*far or near*} and direction {*accommodation or disaccommodation*}.

Latency is the time period (in seconds) between the start of the accommodative stimulus change and the start of the response of the subject. It was computed in the same way as Kasthurirangan *et al*.[23] To find the start of the response an algorithm searched for three consecutive increasing data values, followed by four consecutive data values in which no two consecutive decreases occurred. When these criteria were met, the first data point in the sequence was recorded as the start of the response. The inverse algorithm was used to determine the start of the disaccommodative response. *Response time* was computed as the time period (in seconds) between the start of the accommodative stimulus change and the moment the patient reported clarity and pressed a key. The *accommodative response* at each accommodative demand (half-cycle) was computed as the difference in diopters between the median refraction of the last 4 samples and the median refraction of the first 4 samples. Being the last sample the moment in which the patient reported clarity and the first sample the start of the accommodative stimulus change. Notice that in the hybrid approach only the transitions between 0.17 and 2.17 D and between 0.50 and 4.50 D were considered for the analysis.

Analogously, the accommodative dynamics of each possible accommodative transition within the hybrid condition was analyzed with a repeated measures ANOVA with 2 within-subjects factors: accommodative transition and direction. The accommodative transition had the following 6 levels (in increasing order of accommodative magnitude): {*0.17/0.50, 0.50/2.17, 0.17/2.17, 2.17/4.50, 0.50/4.50, 0.17/4.50*}. This analysis was also conducted for the *latency, response time and accommodative response*.

Statistical power was assessed with the free open source G*Power 3.0.10.[24] Data from a pilot study with 6 subjects was used to compute the required sample size for a statistical power of 0.8. Considering a significance of 0.05 and a paired t-test the required sample size was 14 subjects.

RESULTS

A total of 17 subjects were included in the analysis with a mean age ± standard deviation of 23 ± 2 years.

Repeatability and agreement between manual flippers and the automated test

Repeatability of conditions 1, 2, 3 and 4

The mean difference ± standard deviation (SD) between both sessions (test-retest), the within-subject standard deviation (S_W) and the p-values obtained with the paired sample t-test are shown in table 1 for method and test distance (i.e., conditions 1, 2, 3 and 4).

Table 2. Repeatability (test-retest) for each method and accommodative distance. diff.: difference. SD: standard deviation. S_W: within-subject standard deviation. cpm: cycles per minute.

	Manual Flippers			Automated (EOL system)		
Test distance	Mean diff. ± SD (cpm)	S_W (cpm)	p-value	Mean diff. ± SD (cpm)	S_W (cpm)	p-value
Near	-1±1	1	<0.01	-3±4	3	0.02
Far	-1±1	1	<0.01	-5±4	4	<0.01

Agreement between conditions 1 vs 3 and 2 vs 4

The comparison between the accommodative facility test performed with the manual flipper and the automated accommodative facility test performed with the electro-optical system is shown in the Bland and Altman plots of figure 2 for both target distances. Both methods are also statistically compared with paired t-tests whose p-values are also in figure 2.

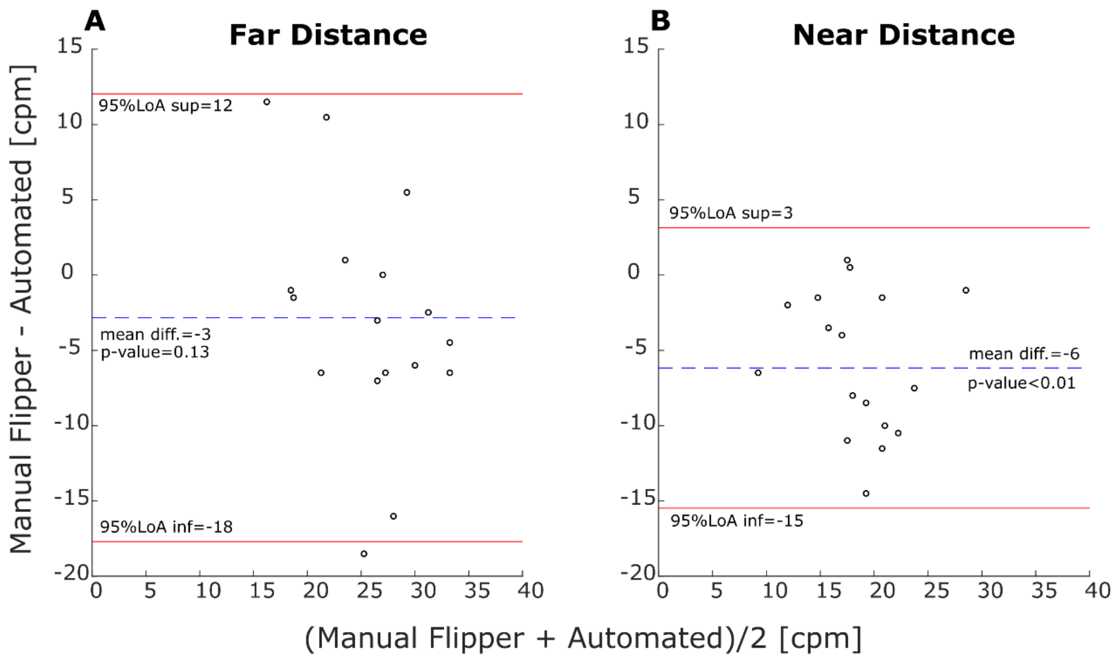

Figure 2. Bland and Altman plots with the 95% Limits of Agreement for far and near distance tests.

Hybrid accommodative facility test

Accommodation dynamics within condition 5

The results of the repeated measures ANOVA applied to *latency, response time and accommodative response* are summarized as follows:

For *latency*, neither the factors (direction and accommodative transition) nor the interaction (*direction*transition*) resulted in statistically significant differences (figure 3 A).

For *response time*, a statistically significant ($p<0.05$) main effect of direction, accommodative transition and also the interaction *direction*transition* was obtained. When controlling for the direction, the Bonferroni post-hoc test showed statistically significant pairwise comparisons when comparing any of the first three levels against any of the remaining three levels for accommodation, and also when comparing the last level against the level 4 and 5 for disaccommodation. When controlling for accommodative transition, significant pairwise comparisons were obtained in the 3 cases that are marked with an asterisk in figure 3 B. The interaction term test*distance was also significant and the post-hoc showed significant differences between far and near regardless of the test (conventional or hybrid).

For *accommodative response,* a statistically significant main effect of direction, accommodative transition and also the interaction *direction*transition* was obtained. In all cases with p-values less than 0.01. When controlling for direction, the Bonferroni post-hoc test showed statistically significant pairwise comparisons in all cases except in the following 4 cases: 1) between the level 2 and 3 for accommodation; 2) between the level 5 and 6 for accommodation; 3) between the level 2 and 4 for disaccommodation; and 4) between the level 3 and 4 for disacommodation. When controlling for accommodative transition, significant pairwise comparisons were obtained only in 2 cases that are marked with an asterisk in figure 3 C.

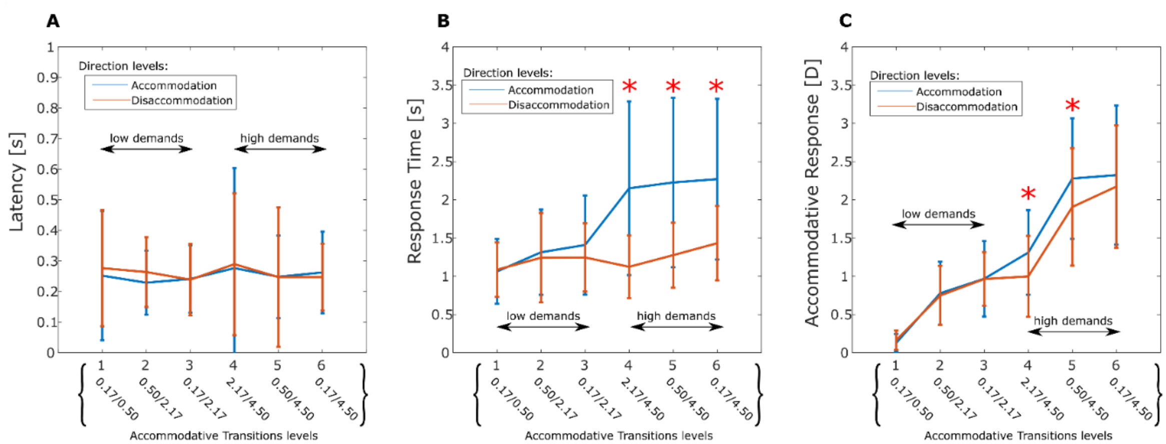

Figure 3. Accommodation dynamics within condition 5. Latency, response time and accommodative response as a function of the accommodative demand factor controlling for direction. Red asterisk indicates statistically significant differences (p<0.05). Error bars are standard deviations.

Accommodation dynamics among conditions 3, 4 and 5

The results of the repeated measures ANOVA with 3 within-subjects factors (with 2 levels each) conducted for the *latency, response time and accommodative response* are summarized in table 2.

Table 3. P-values obtained with the repeated measures ANOVA. Statistically significant values are in red.

	Latency (s)	Response Time (s)	Accommodative Response (D)
Test	0.96	0.98	0.22
Distance	0.93	<0.01	<0.01
Direction	0.68	0.01	<0.01
*Test*Distance*	0.69	0.04	0.49
*Test*Direction*	0.36	0.21	0.91
*Distance*Direction*	0.65	<0.01	<0.01
*Test*Distance*Direction*	0.57	0.07	0.17

Latency is not affected by the predictability of the stimulus, the direction of accommodation, the accommodative demand and any of the interactions amongst these variables. Contrary, there is a main effect and interaction of distance and direction in both response time and the accommodative response, the Bonferroni post-hoc tests for the interaction term are shown in table 3. Additionally, there is a slight statistically significant difference in the interaction term *Test*Distance* for response time. The Bonferroni post-hoc test is shown in table 4.

Table 4. The Bonferroni post-hoc test of the significant interaction *Distance*Direction* for response time and the accommodative response.

		Response Time		Accommodative Response	
		Mean diff. ± SD (s)	p-value	Mean diff. ± SD (D)	p-value
Distance	Direction				
Far	Acc.-Disacc.	0.26 ± 0.77	0.18	0.05 ± 0.19	0.27
Near	Acc.-Disacc.	0.75 ± 0.88	<0.01	0.33 ± 0.28	<0.01
Direction	Distance				
Accommodation	Far-Near	-0.56 ± 0.57	<0.01	-1.31 ± 0.38	<0.01
Disaccommodation	Far-Near	-0.07 ± 0.29	0.33	-1.03 ± 0.51	<0.01

Table 5. The Bonferroni post-hoc test of the significant interaction *Test*Distance* for response time.

		Mean diff. ± SD (s)	p-value
Distance	Test		
Far	Conventional-hybrid	0.11 ± 0.27	0.12
Near	Conventional-hybrid	-0.11 ± 0.28	0.14
Test	Distance		
Conventional	Far-Near	-0.21 ± 0.37	0.03
Hybrid	Far-Near	-0.42 ± 0.32	<0.01

DISCUSSION

On the one hand, this study compared (in terms of precision and agreement) the conventional manual flipper accommodative facility test with an automated test performed in a computer-controlled electro-optical system. On the other hand, a new accommodative facility test with 4 accommodative demands (that are presented in an unpredictable manner) is presented and its accommodation dynamics performance is analyzed.

Repeatability and agreement between manual flippers and the automated test

The automated test performed in a computer-controlled electro-optical system is less repeatable than and it does not agree well with the manual flipper test at both target distances. The within-subject standard deviation that was obtained for both accommodative facility methods is consistent with McKenzie *et al*.[25] who obtained a within-subject standard deviation of 3 cpm in subjects from 8 to 12 years old using the manual flippers. However, there are some remarkable differences between both methods that can account for the poor agreement. Among them, factors such as the field of view (which is larger in the manual flipper) or the magnification (which is constant in the automated test can contribute to these differences, however, we believe it is the fact that the automated test rolled out the response time of the clinician doing the transition between lenses, which can be of the order of 0.6 seconds/transition,[8] the main cause of the poor agreement. Given that a young healthy subject can easily perform around 15 to 25 cycles per minute (as shown in figure 2), the total time spent by the clinician may add up to between 9 and 15 seconds (e.g., 15x0.6=9). Given also that the average response time per transition can go from 1 to 2.5 seconds (as shown in figure 3B), the number of potential cycles 'gained' in one minute due to automatization can be between 2 to 8 (e.g., 9/(2x2.5)≈2). This range covers well the mean absolute difference found between both methods that are 3 and 6 cpm for far and near accommodative facility tests. According to our results, accommodative facility measurements obtained from either automatized or manual flippers are not comparable and should not be interchanged.

Hybrid accommodative facility test

There are a couple interesting outcomes that caught our attention in regards to the hybrid approach where both far and near accommodative facility tests are automated and integrated into only one test that randomizes among the 4 accommodative demands. The first one was the lack of any predictability effect. We did expect latency to be larger for unpredicted stimuli but no effect was found at all. In this sense, few studies carried out more than 40 years ago concluded that the prediction operator in accommodation exists and has a small but considerable impact in latency,[9–11] however, these studies were limited in sample size (they only studied 1 to 4 subjects, who were probably the experimenters) and difficult to reproduce due to the lack of information about the typology of participants or the explicit task instructed to them. These factors may have biased their results, as it was shown in posterior studies, the accommodative response and some parameters of its dynamics (e.g., latency) are affected by age,[20,26] refractive error[8] and the task instructions given to participants.[27] Our hypothesis is that predictability does not affect accommodation *per se* but that with training it may shorten latency, although further studies are required to disentangle the isolated effect of stimulus' predictability in time, magnitude and direction, as well as their interactions, on accommodation dynamics.

The second interesting outcome was that the response time and accommodative response were affected by the direction of accommodation for high accommodative demands only. In other words, for disaccommodation, the mean response time was around 1 second regardless of the accommodative demand, however, for accommodation, the response time was around 1 second for low accommodative demands and it increased abruptly up to 2.5 seconds for higher demands. Similarly happened with the accommodative response, the differences between accommodation and disaccommodation seemed to increase with the accommodative demand. Despite there was a large variability across subjects in both the response time and accommodative response, the previously mentioned effects are statistically significant and are consistent with previous studies.[8,23]

Moreover, the linkage between accommodative demand and direction of accommodation also appeared when comparing the hybrid test with the automated far and near accommodative facility test. There was a significant interaction between the distance and direction of accommodation in both response time and accommodative response, and significantly larger values were obtained for near distance than far distance during accommodation regardless of the test type (conventional or hybrid). Radhakrishnan *et al*.[8] also found significantly larger response times for accommodation than disaccommodation at near distances although this difference was found only in myopes. Thus, it may be possible that the differences found in our study are enhanced by the myopes of our sample (which were exactly the 53% of the sample). Certainly, the accommodative response is affected not only by the experimental conditions[12] but also by the observer's refractive error.[14]

In conclusion, our results showed that the hybrid approach is able to provide a more comprehensive examination of the accommodative capability to change focus over time than the conventional accommodative facility test. Despite its potential advantage, it would be valuable in further studies to replicate these same results but including accommodative dysfunctions and refractive error as covariates to study whether the current normative values of accommodative facility should be redefined in the context of the hybrid approach as well as to see whether this new test is more sensitive to accommodative anomalies than the conventional accommodative facility tests.

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APPENDIX

OPHTHALMIC AND PHYSIOLOGICAL OPTICS NORMATIVE

1. Title page. To include the full title (limited to 70 characters), running head (i.e. abbreviated title limited to 50 characters that will appear as a header on each page of the paper), author's names and institutional affiliation, corresponding author with e-mail address and keywords.

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6. Introduction should succinctly provide the research rationale without extensively reviewing the literature.

7. Methods should describe the experimental design, subjects used and procedures followed in sufficient detail that others could duplicate the research. Include details of ethical standards followed where appropriate. All measurements must be given in SI or SI-derived units. Chemical substances should be referred to by the generic name only. If proprietary drugs have been used in the study, refer to these by their generic name, mentioning the proprietary name, and the name and a weblink for the manufacturer, in parentheses. Commercially available equipment should be identified by the type of instrument, its maker and the model number, with provision of an appropriate website address where possible.

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8. Results should include a minimum of discussion. The statistical approach recommended by *OPO*is presented in Armstrong and colleagues (*OPO*, 2011). Studies that assess agreement between tests or the repeatability of test results should consult McAlinden et al. (*OPO*, 2011). For issues regarding the use of data from one or both eyes of patients, consult Armstrong (*OPO*, 2013) and for issues regarding the use of multiple statistical tests and/or the Bonferroni correction, consultArmstrong (OPO, 2014). Other useful guidelines, including the assessment of data that are not normally distributed, are available at: http://statistics-group.nihr.ac.uk/research/ophthalmology/.

Altman and colleagues' (*BMJ*, 1983) statistical guidelines for the presentation of results are also recommended:

- Do not add spurious precision to data so that mean values should be no more than one decimal place more than the original data (e.g. mean logMAR could be 0.12 or 0.124, but not 0.12386). Percentages can often be rounded to the nearest whole number.
- Report the results of statistics tests (e.g. F or t-value) and degrees of freedom in addition to p-values and give exact p-values to 2 significant figures unless $p<0.0001$ (e.g., $F_{2,94}=0.31$, $p=0.73$; $F_{2,4} = 4.26$, $p = 0.015$, $F_{1,94}=17.1$, $p<0.0001$)
- Always present means (or medians) with standard deviation (SD) or standard error (SE) values (or inter-quartile range and/or full range). Provide SD or SE values in brackets rather than using the ± sign as it avoids any confusion between SD and SE.
- Use colour in all figures as this is free to authors. It may be useful to also differentiate different columns, datapoints etc in other ways to allow differentiation when printed in black and white.

9. Discussion. Highlight the key features of the results and their interpretation and do not merely reiterate the results. Include any limitations of the study.

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